

Future colliders

Making the case

Harry Cliff, University of Cambridge

Second ECFA Workshop, Paestum, 2023

Introduction

To state the obvious:

A clear, compelling argument for why we should build a future collider is essential.

Will outline a few approaches taken by others so far, both to the community and to the public.

Non-exhaustive and (hopefully) not too specific to any one project.

Who do we need to persuade?

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The public

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**Future
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**Politicians
& decision
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**Future
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Who do we need to persuade?

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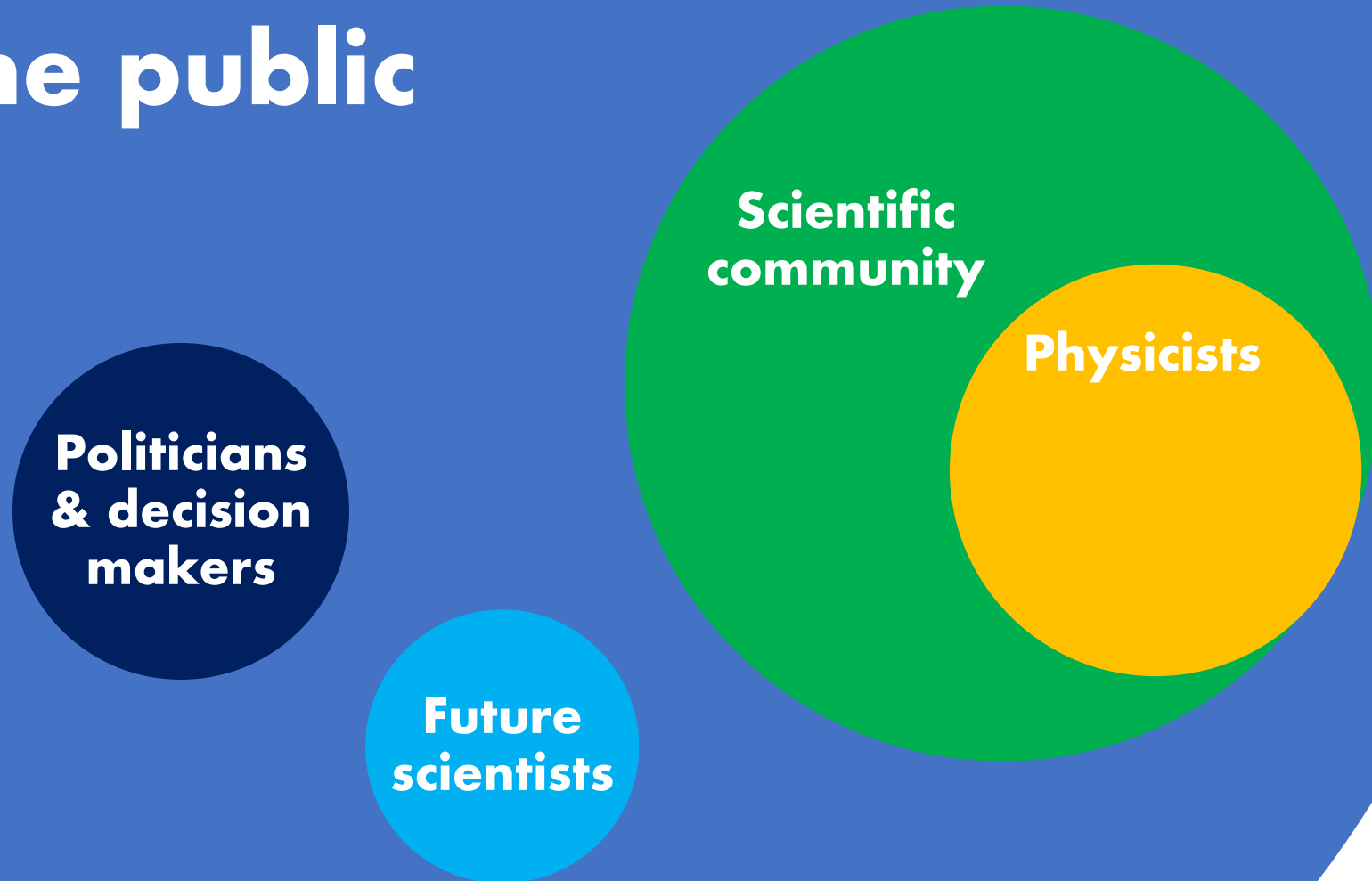
**Politicians
& decision
makers**

**Future
scientists**

**Scientific
community**

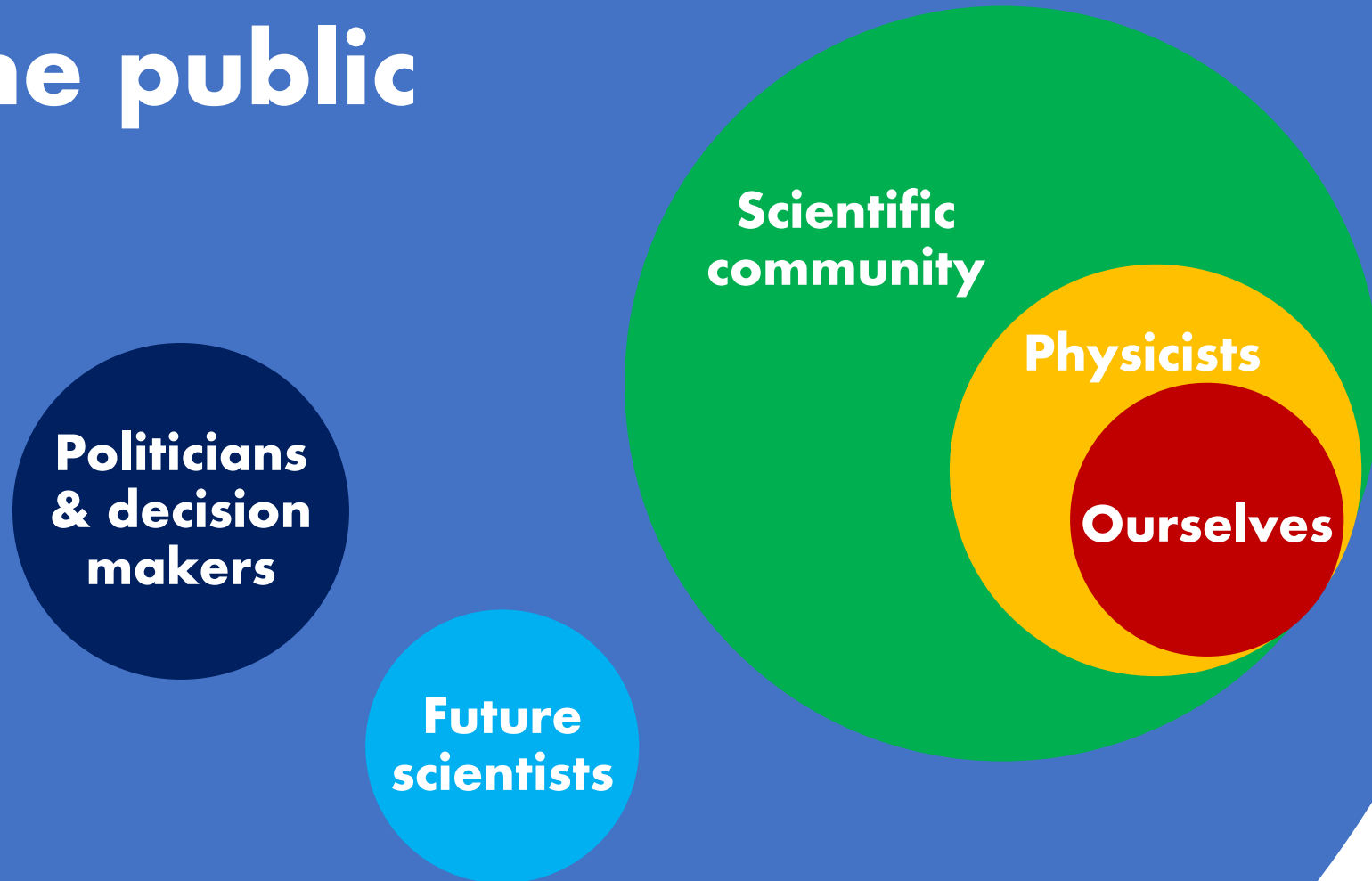
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The LHC Message



The LHC Message

FIND THE HIGGS*
SEARCH FOR NEW PHYSICS

*or something else

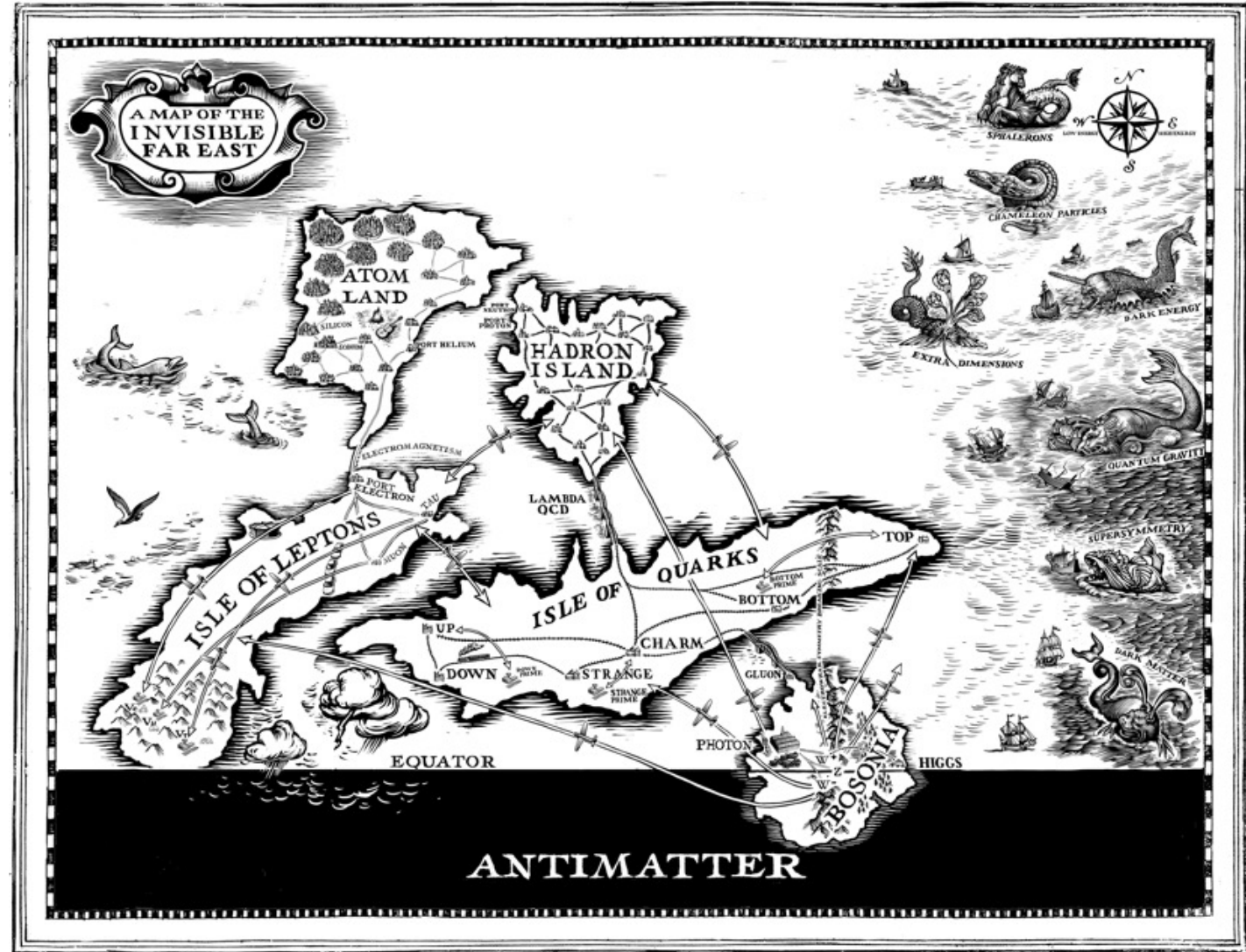
The message for a future collider?

Particle Physics as Exploration



We should be more prepared to make the case that colliders are for exploration – in the same way as big telescopes.

(My paraphrasing)



Particle Observatories

CERN COURIER | Reporting on international high-energy physics

Physics ▾ Technology ▾ Community ▾ In focus Magazine



ACCELERATORS | OPINION

Future colliders are particle observatories

3 July 2023

Colliders are not just searches for new physics; they are general-purpose observatories of fundamental processes on the smallest scales. We need to start thinking of them as such, says Tevong You.



Particle Observatories

Cosmology and astrophysics... are fundamental sciences whose aim is nothing more than to better understand the objects within their remit. Telescopes and other instruments point at the universe at large, observing to ever higher precision, farther than ever before, in new, previously inaccessible regimes.

Particle physics is pushing the boundaries of our understanding in the other direction – looking inwards rather than outwards.



Particle Observatories

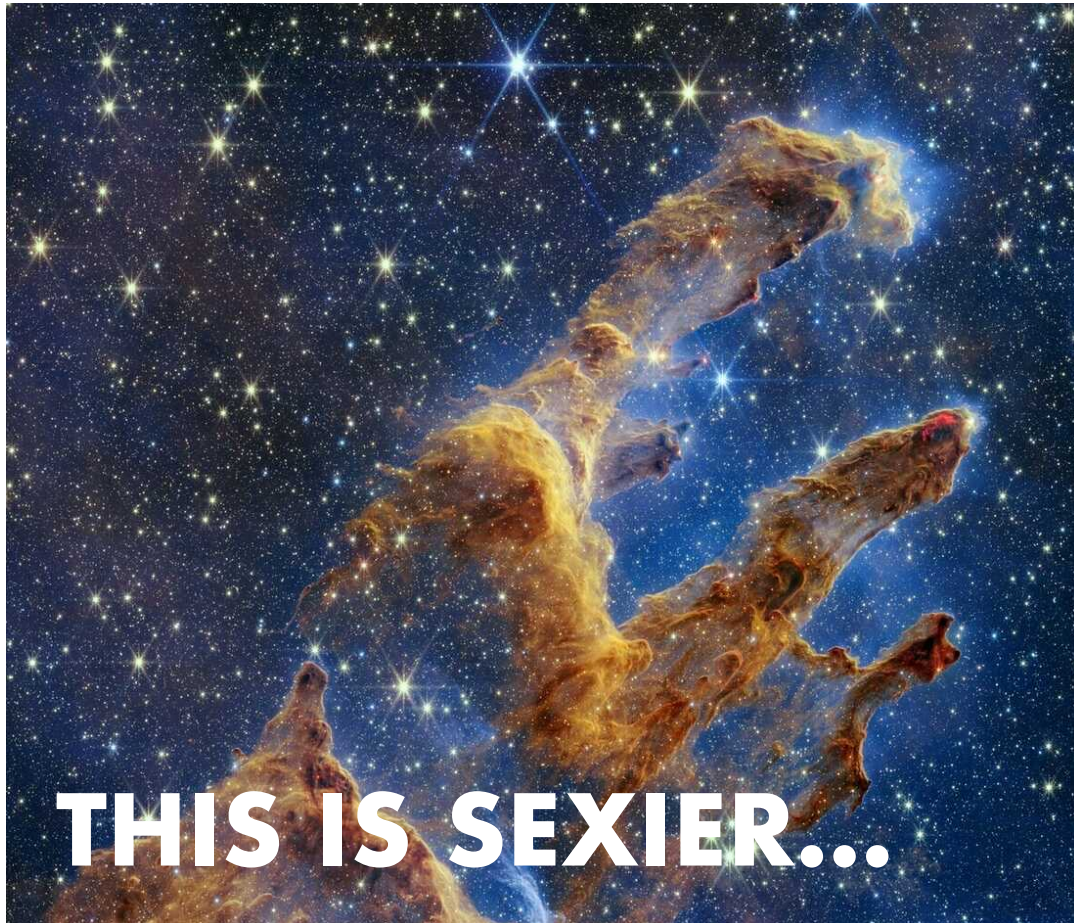
In no other field of science is the promise of revolutionary discovery the only standard by which future proposals are held.

Yet in particle physics a narrative persists that the current lack of new physics beyond the Standard Model (SM) is putting the future of the field in doubt. This pessimism is misguided.

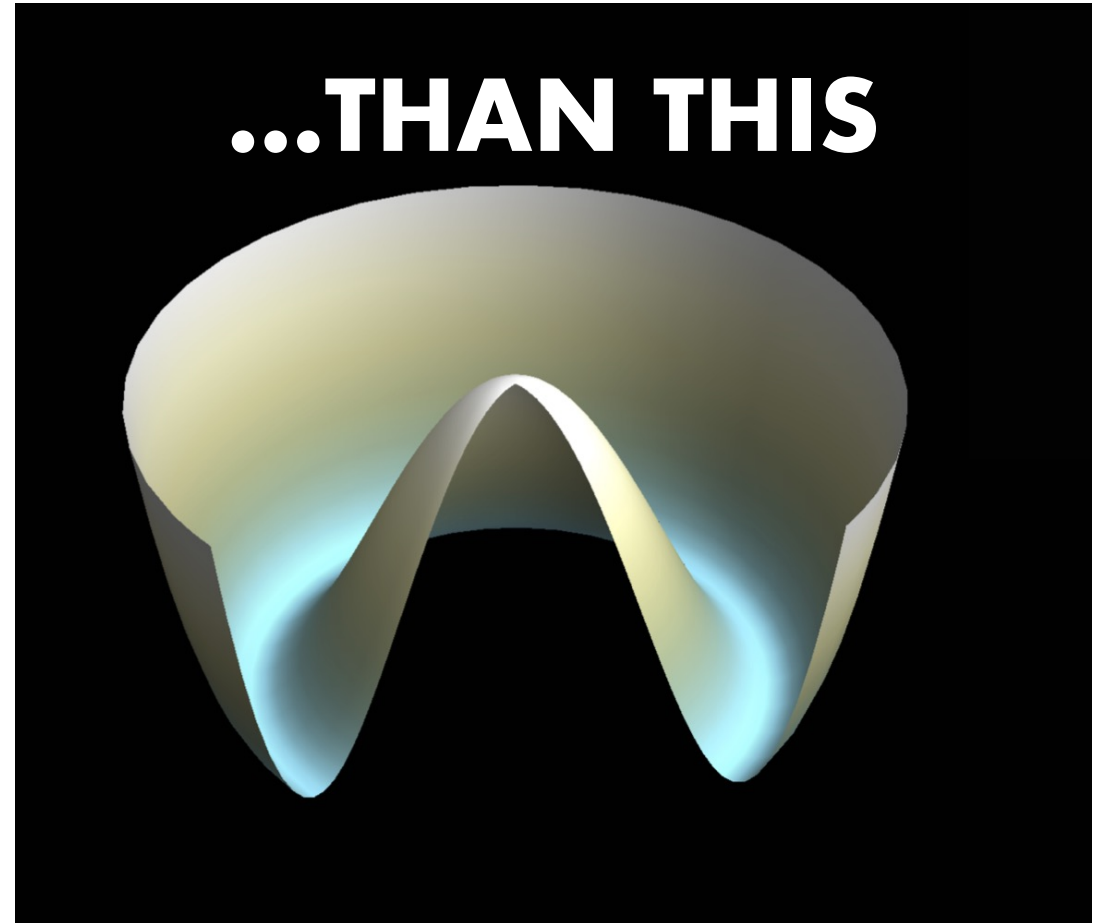
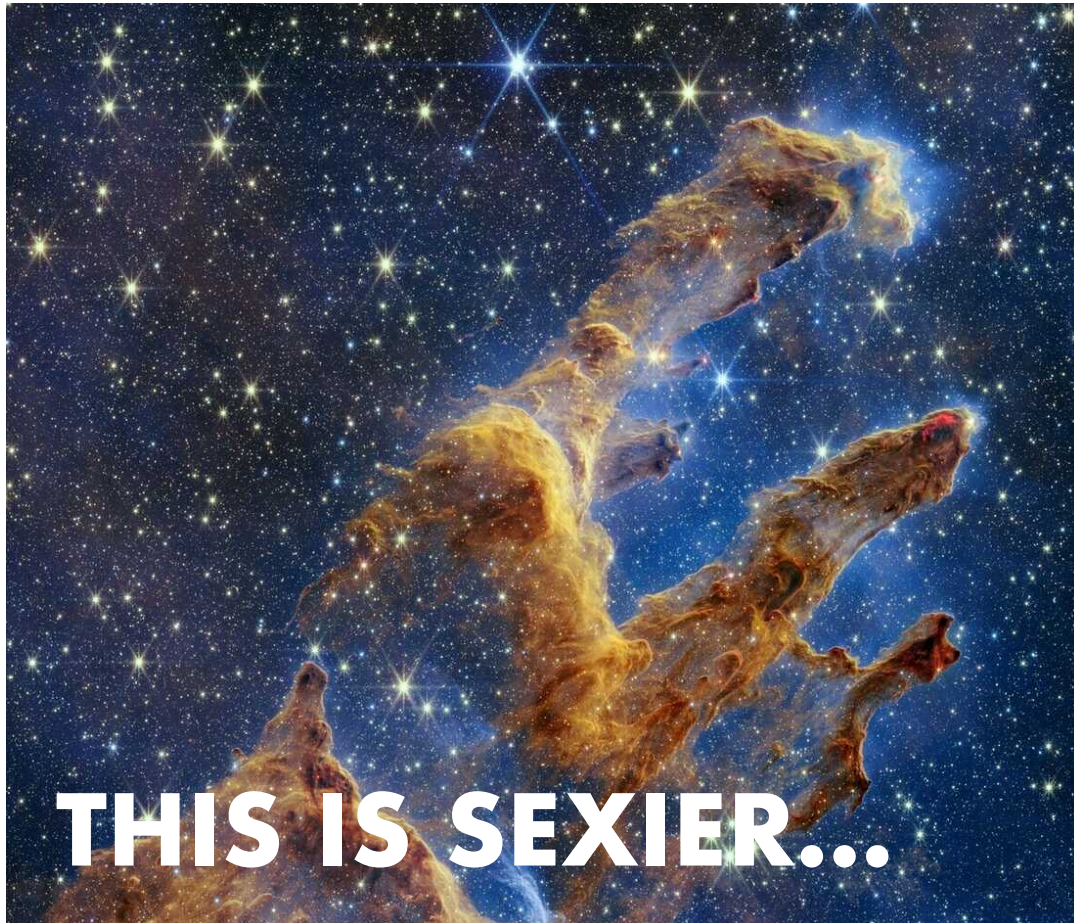
Tevong You



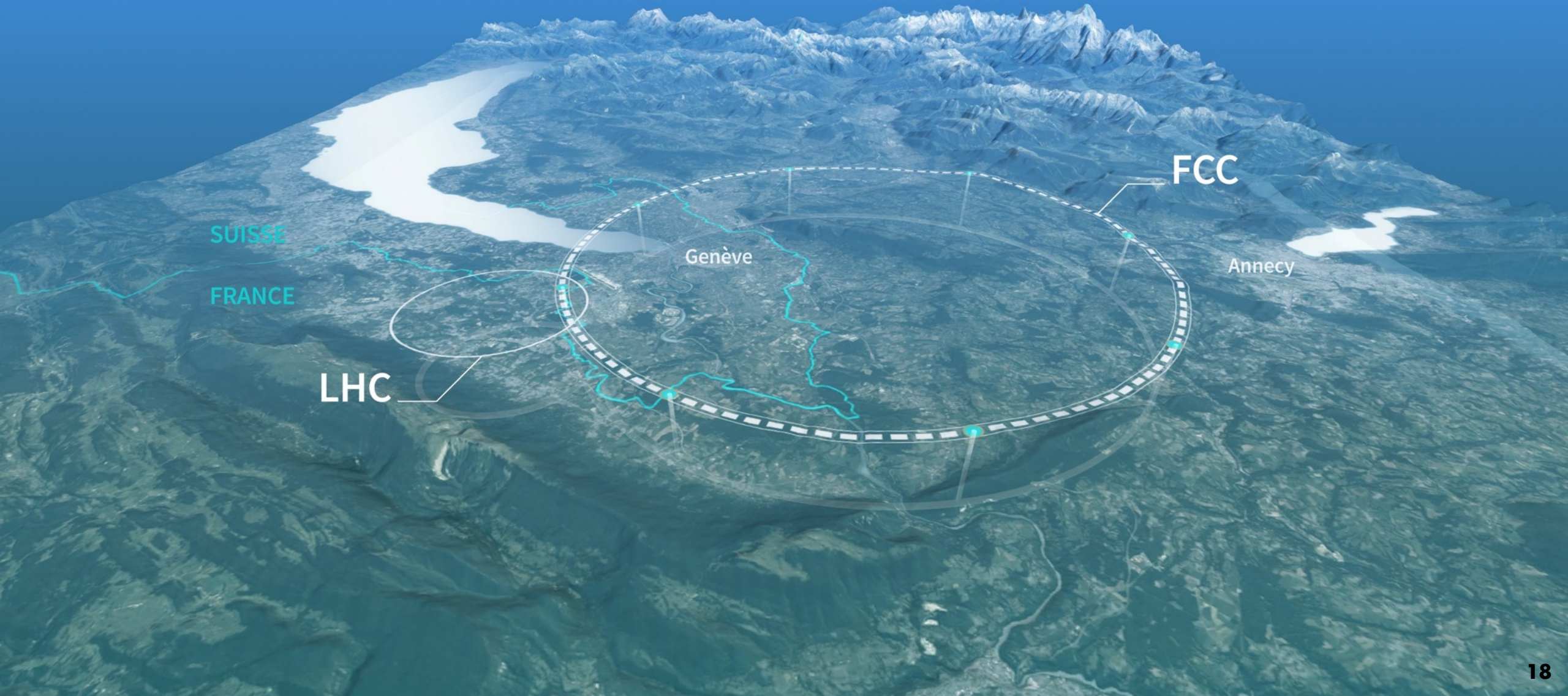
Some challenges



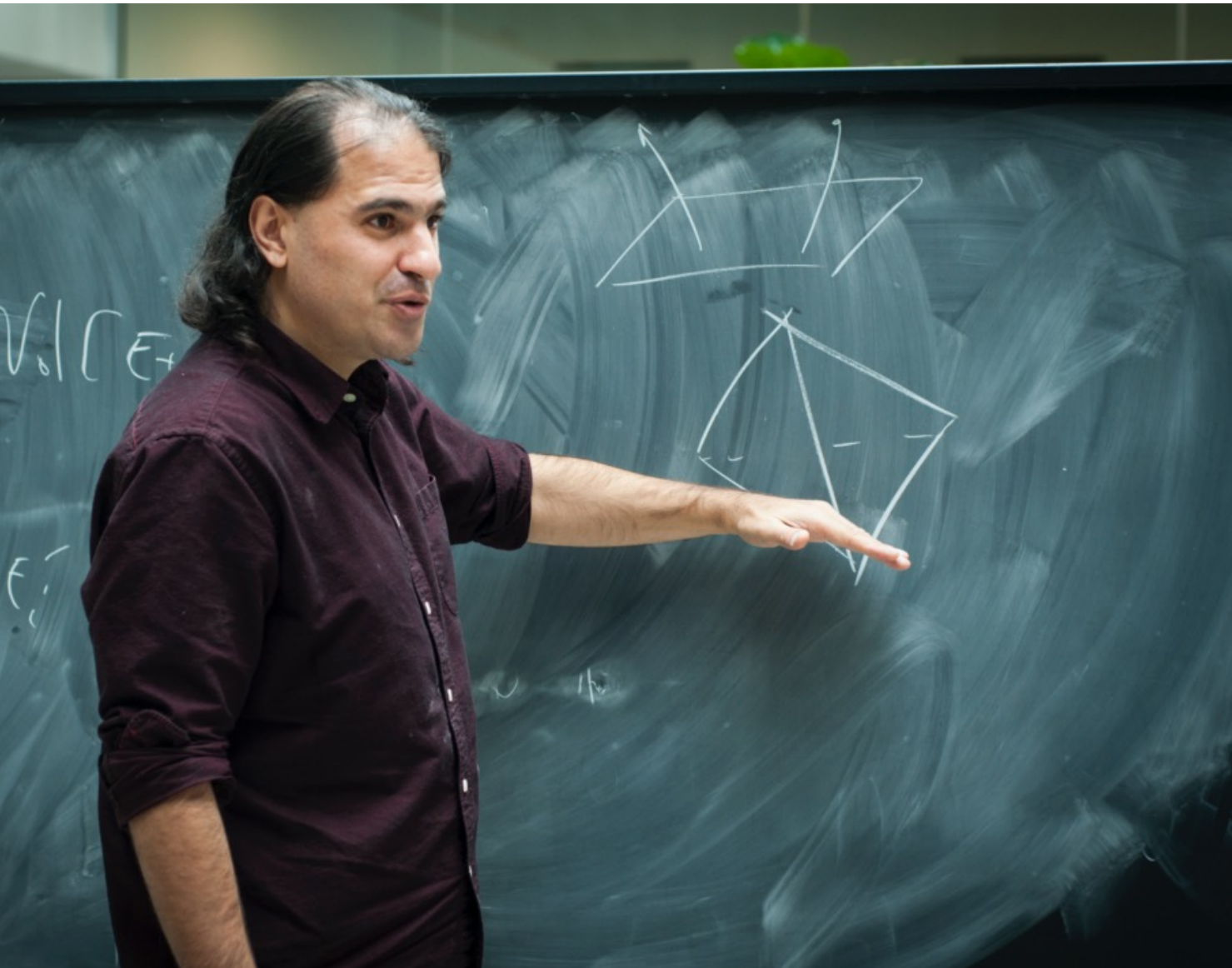
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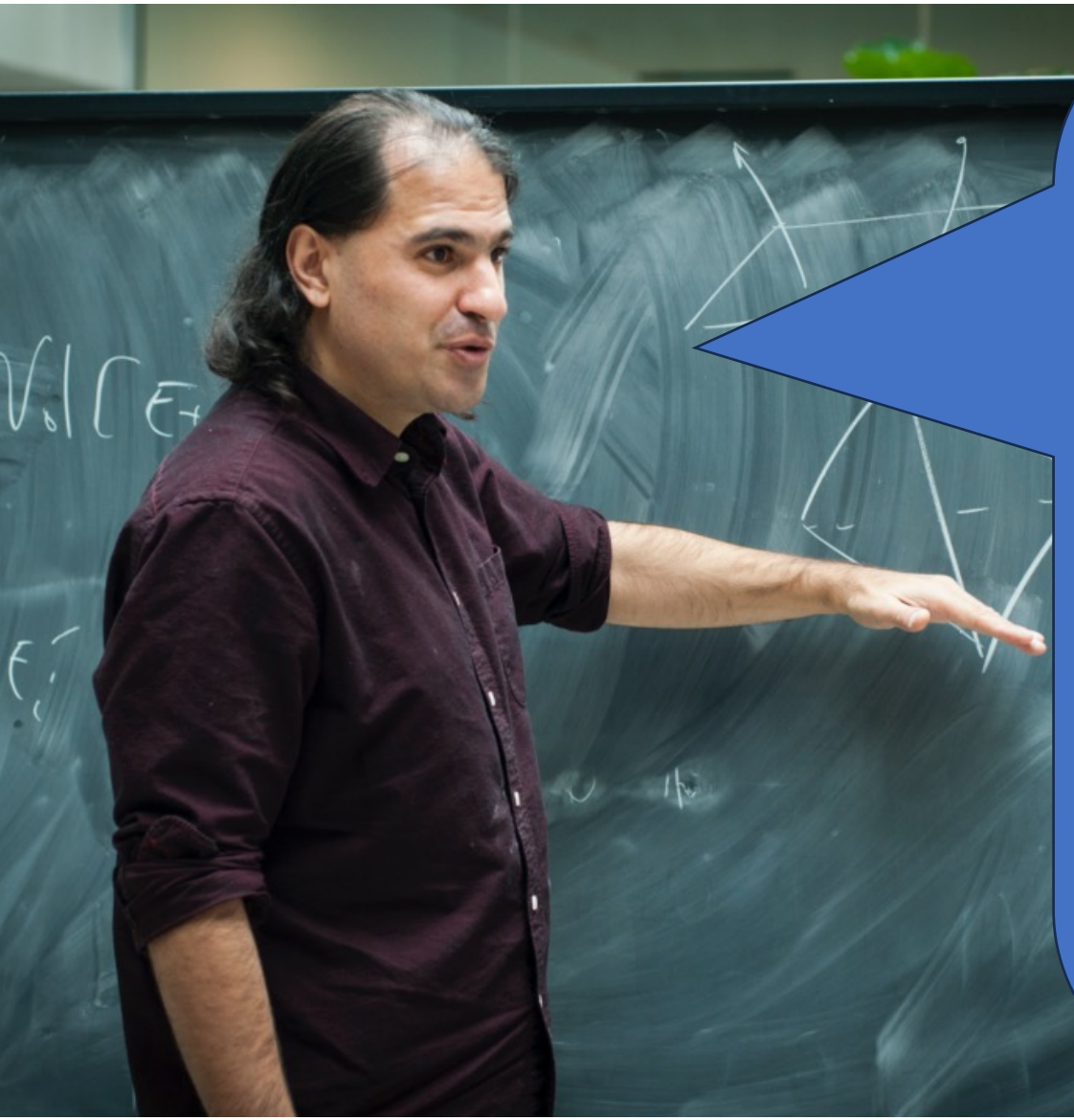
Some challenges - ambition



A Deep View of the Laws of Nature



A Deep View of the Laws of Nature



There are some people thought particle physics was about seeing bumps in a plot and going to Stockholm. And they say, look, it's even built into the name of the goddam subject!

For me that was not the attraction at all, it made it feel a bit like chemistry, and I sucked very badly at chemistry. All these particles, all these funny names, were actually a barrier to me that I had to overcome. **What got me into it is you get this amazing view of the deep workings of the laws of nature. That's what it's really about!**

Nima Arkani-Hamed

Taking the 'Standard' out of Standard Model?

... about selling strategies

Maybe we could have done better?!

"If you want to buy a car, would you buy the Standard Model? – No."

(Hans Kühn, a multi-loop pioneer)

Car manufacturers have abandoned this name more than 100 years ago!

Standard Model 'S' (1913 - 1918)

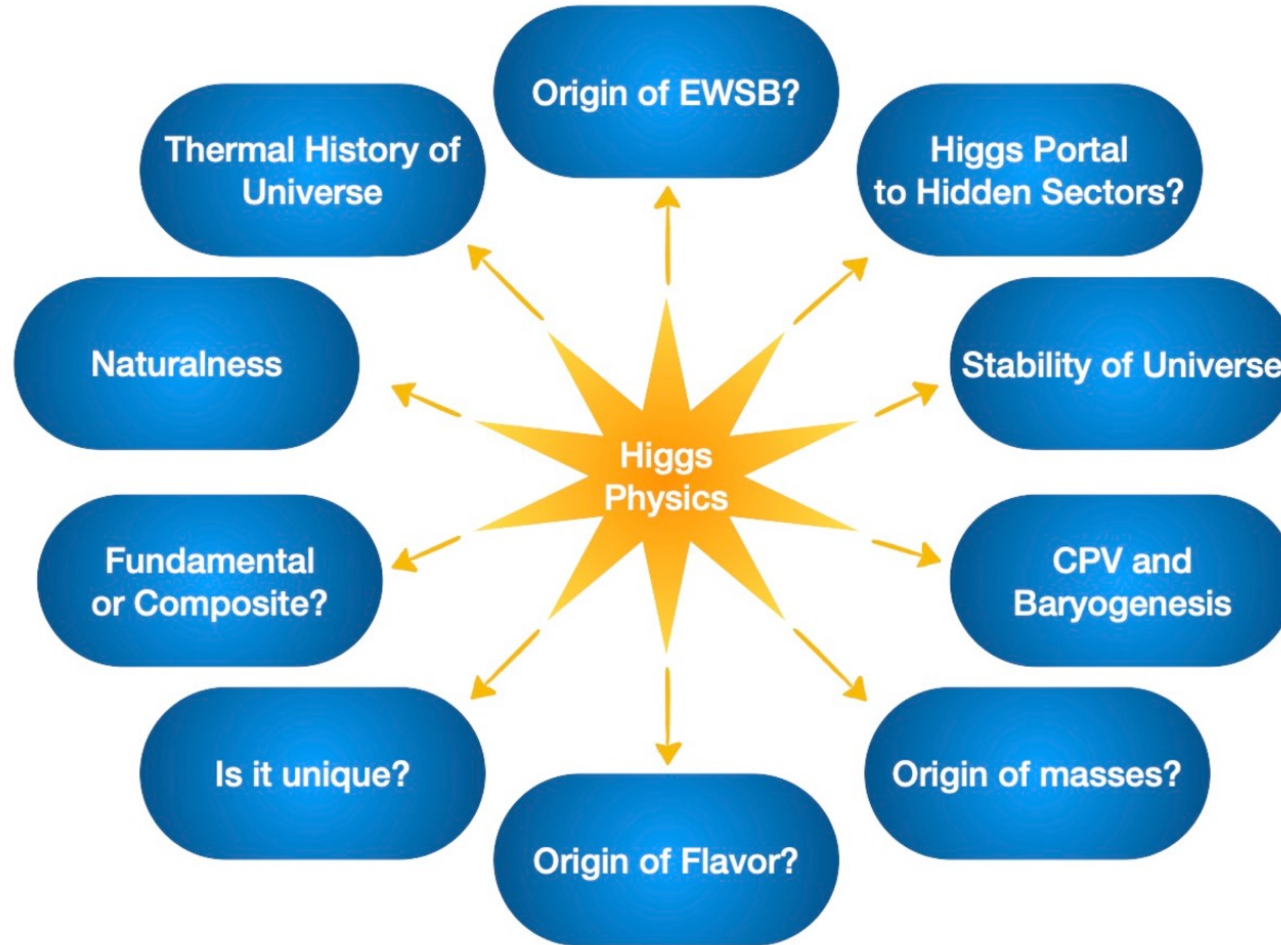
Standard's first entry into the Light Car Market and introduction to Mass Production



THE 'ALL-BRITISH' STANDARD LIGHT CAR

(<http://www.standardregister.co.uk/id16.html>)

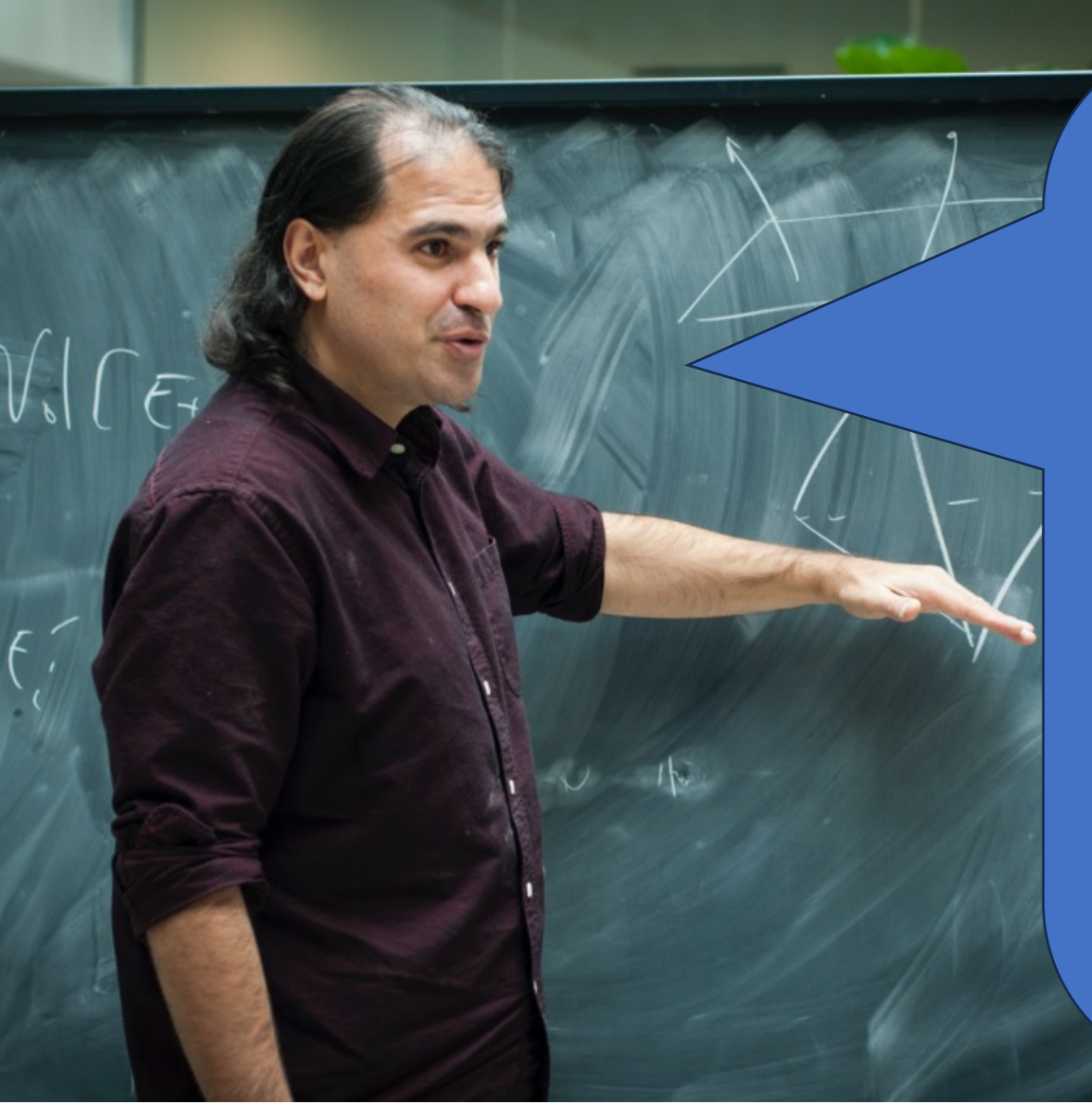
The Higgs at the Centre



Is there a NO-LOSE THEOREM?

Stolen from Gavin Salam's [FCC week talk](#)

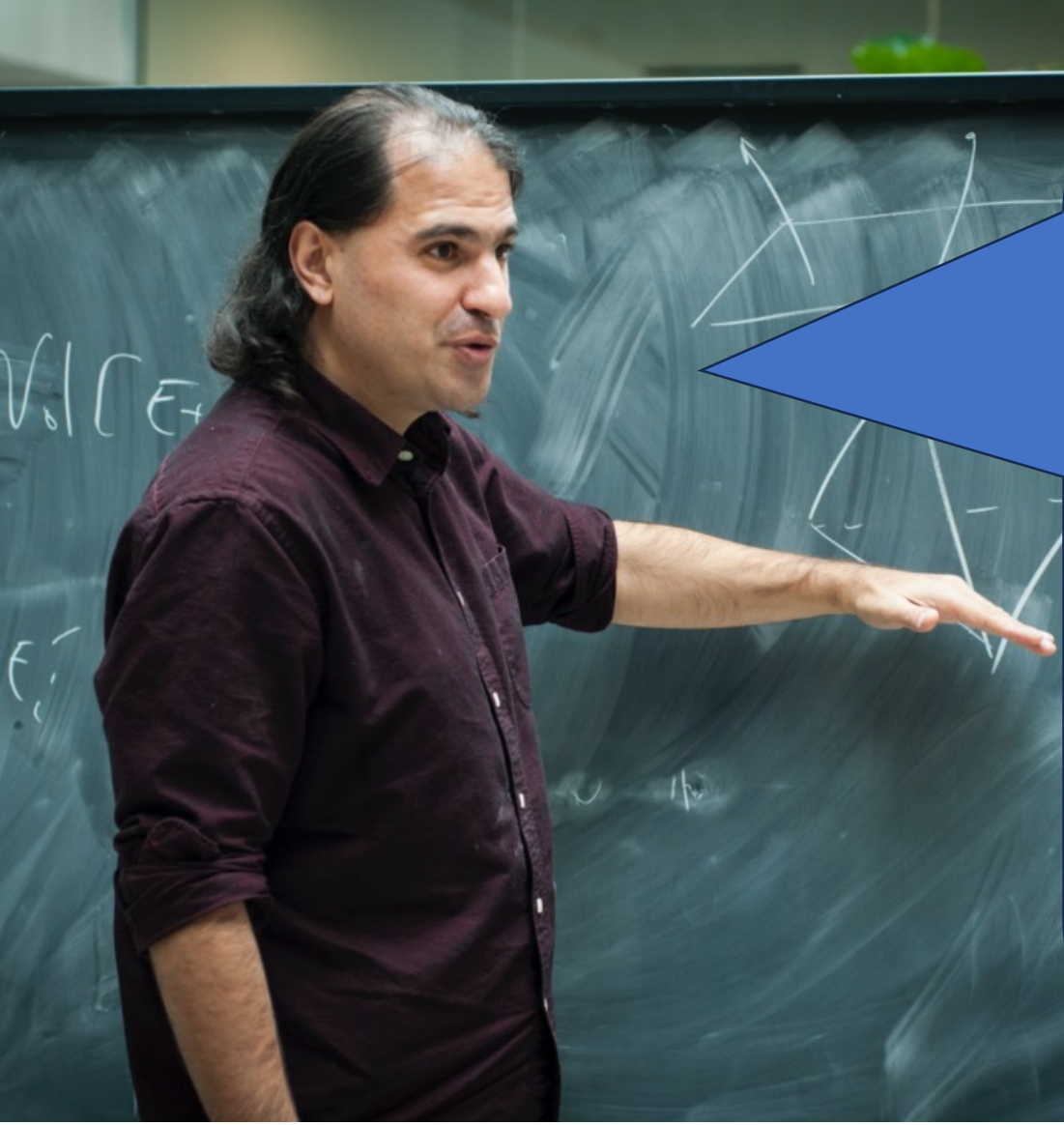
Studying the Higgs to death



We have never seen anything like the Higgs before. This is not hyped, it's not like we're making a big deal about the latest particle.

The Higgs is the first elementary particle of spin zero we've ever seen, it's the simplest elementary particle we've ever seen, it doesn't have any charge, the only property that it has is mass and the very fact that it's so simple is what makes it really theoretically perplexing!

Studying the Higgs to death



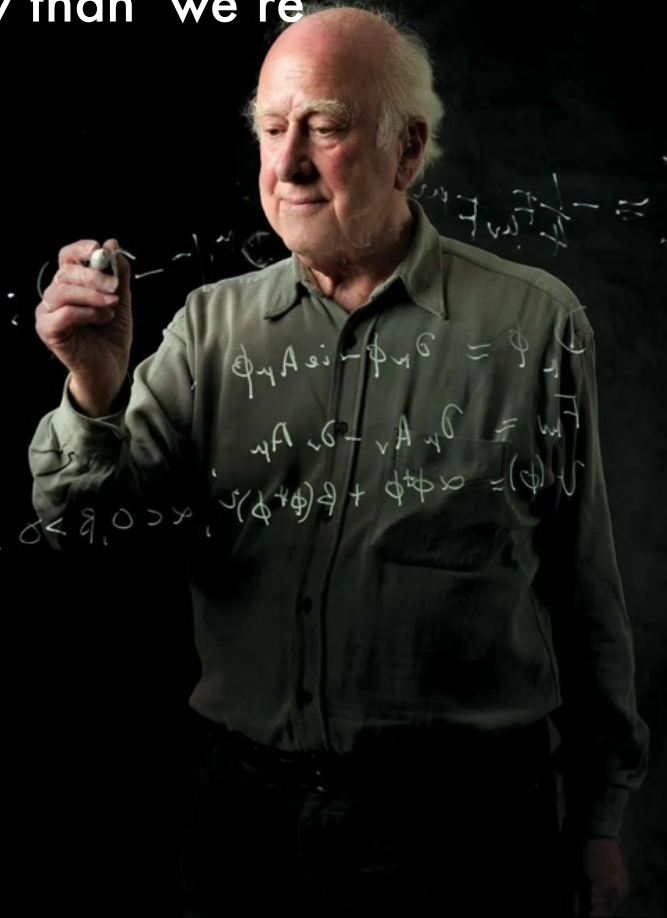
The Higgs is really profoundly new physics, we've really never seen anything like it, and putting it under a microscope is easily enough of an argument to build the next machine.

Nima Arkani-Hamed

A story for the Higgs

Questions related to the Higgs tend to be abstract. Harder to convey than 'we're going to discover a new particle' e.g.

1. Does the Higgs couple to the first generation as expected?
2. What is the natural width of the Higgs?
3. What is the form of the Higgs potential?



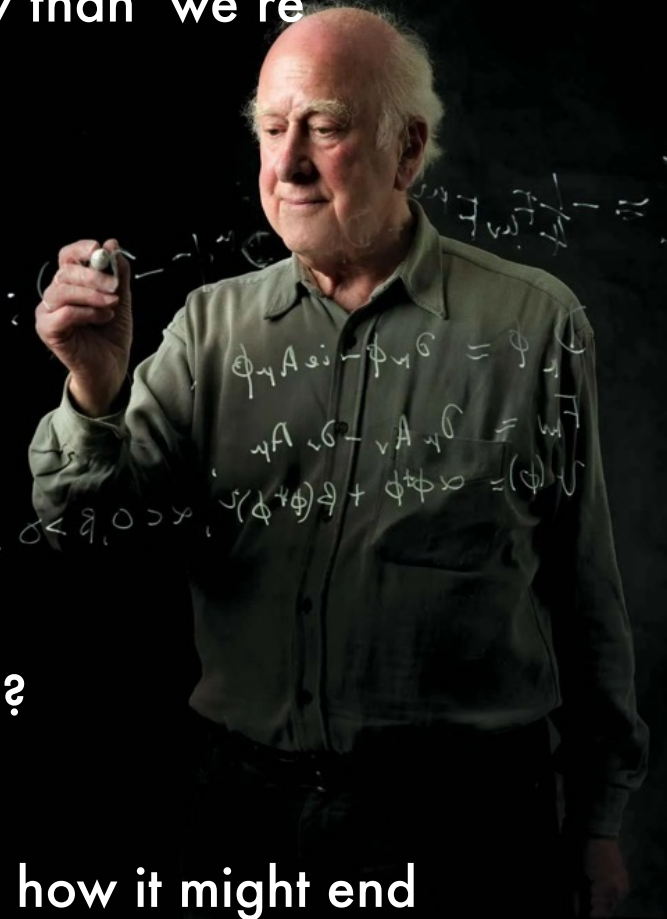
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Can we boil this down to a set of comprehensible messages? e.g.

1. Does the Higgs really give mass to the particles we're made from?
2. The Higgs *could* be a doorway to the dark universe
3. Understanding the Higgs will tell us how our universe formed and how it might end



Beyond Physics

Need to have all the usual side-arguments up our sleeve:

- spin off tech
- value of international collaboration
- inspiration factor
- investment in high tech industries
- training of technical specialists
- far future applications of fundamental discoveries?



Responding to criticism

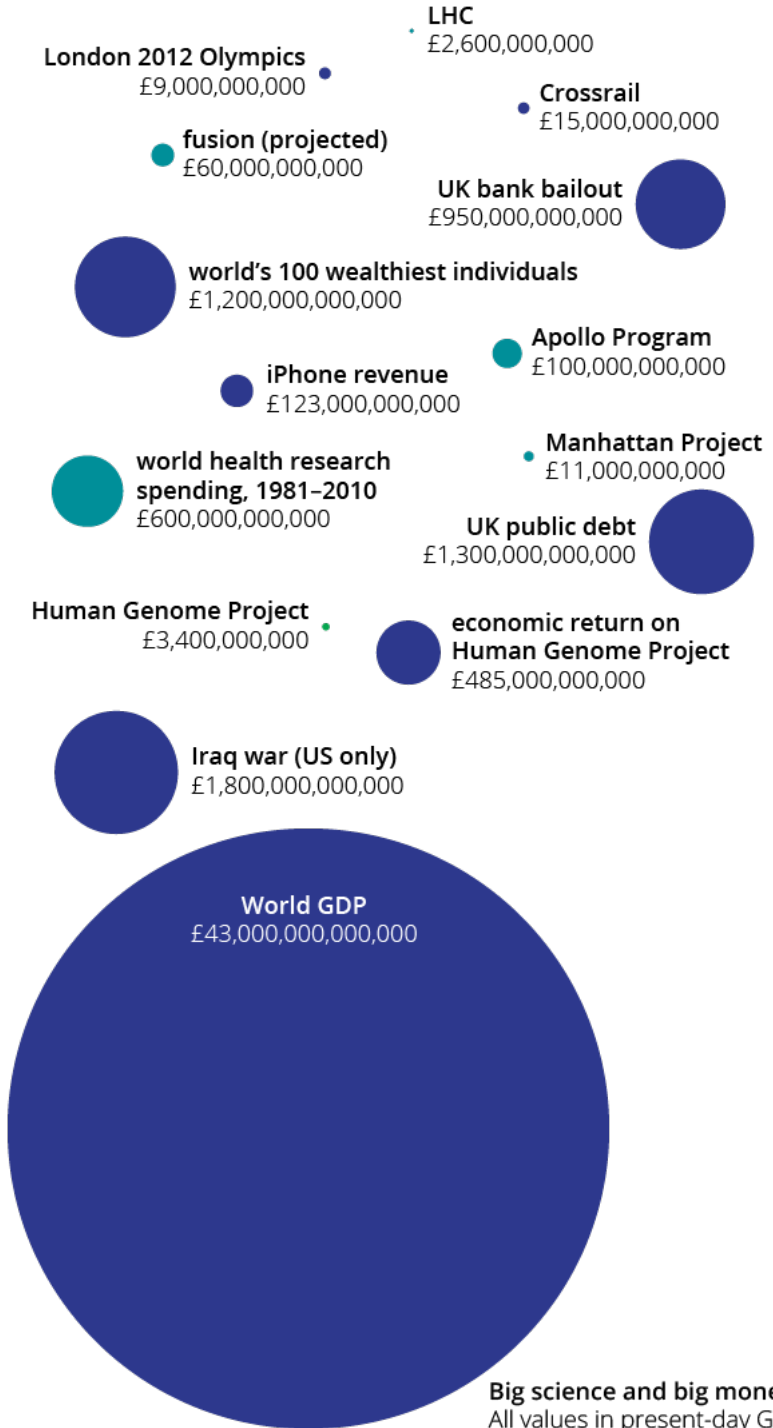
- That's very expensive!
- You promised to find dark matter/SUSY/black holes at the LHC and didn't
- Why aren't you solving climate change?
- Particle physicists just make up hypothetical particles to justify expensive experiments
- You're trying to open a portal to Hell. etc etc

On Money

Costs of future colliders sound astronomical – tens of billions of euros/dollars.

Should try to put these costs in context – e.g. cost per citizen per year / comparison with other large projects.

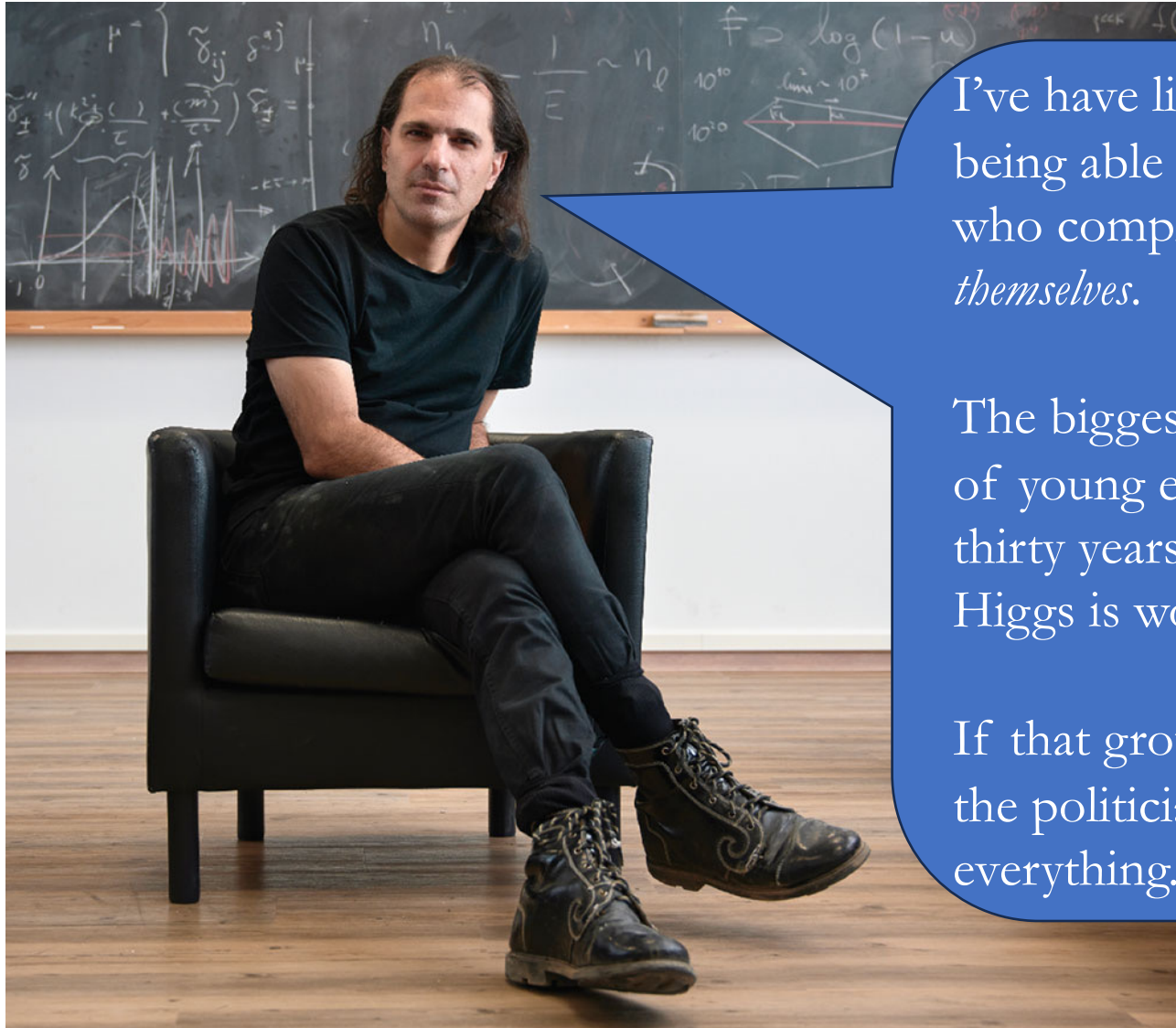
Great work by Andrew Steele on this at www.scienceogram.org



Discovering the Higgs boson literally cost peanuts.

The UK subscription to CERN and the LHC costs us £1.50 per person per year; about the same as we spend on peanuts.

The Biggest Bottleneck



I've have little sympathy for the belly aching about not being able to convince politicians. I find that the people who complain about this most of all can't convince *themselves*.

The biggest bottleneck is: Is there a big enough group of young experimentalists who think devoting twenty, thirty years of their lives to studying the hell out of the Higgs is worth it?

If that group of people does not exist, forget it! Screw the politicians, screw all the arguments, screw everything.

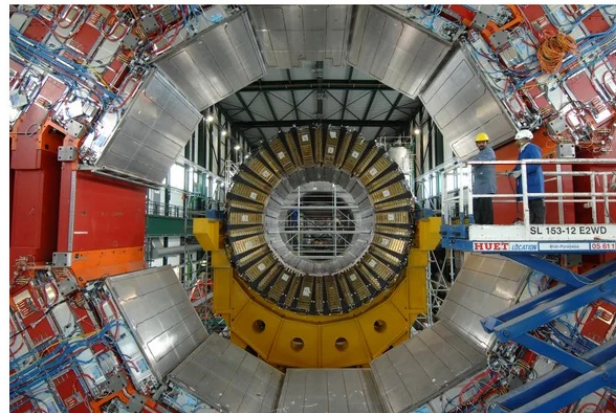
PANEL DISCUSSION

POLICY | OPINION

The World Doesn't Need a New Gigantic Particle Collider

It would cost many billions of dollars, the potential rewards are unclear—and the money could be better spent researching threats such as climate change and emerging viruses

By Sabine Hossenfelder on June 19, 2020



The CMS detector, one of four major particle detectors at the Large Hadron Collider. Credit: Lionel Flusin *Getty Images*

This is not the right time for a bigger particle accelerator. But [CERN](#), the European physics center based in Geneva, Switzerland, has plans—big plans. The biggest particle physics facility of the world, currently running the biggest particle collider in the world, [has announced](#) it aims to build an even bigger machine, as revealed in a press conference and [release](#) today.

With that, CERN has decided it wants to go ahead with the first step of a plan for the Future Circular Collider (FCC), hosted in a ring-shaped tunnel 100 kilometers, or a bit over 60 miles, in circumference. This machine could ultimately reach collision energies of 100 tera-electron-

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The Standard Model still has some loose ends, but experimentally testing those would require energies at least ten billion times higher than what even the FCC could test. The scientific case for a next larger collider is therefore presently slim.

too much science funding is handed out on the basis of inertia. In the past century, particle physics has grown into a large, very influential and well-connected community. They will keep on building bigger particle colliders as long as they can, simply because that's what particle physicists do, whether that makes sense or not.

there is no reason why the particles that make up dark matter or dark energy should show up in the new device's energy range.

It's about time society takes a more enlightened approach to funding large science projects than continuing to give money to those they have previously given money to. We have bigger problems than measuring the next digit on the mass of the Higgs boson.

particle physicists should focus on developing new technologies that could bring colliders back in a reasonable price range and hold off digging more tunnels.